United States Army
Tank-Automotive Command

Warren, Michigan 48090

FOREIGN INTELLIGENCE OFFICE

TACOM

INNOVATIVE MOBILITY DESIGNS UTILIZED ON FOREIGN WHEELED & TRACKED VEHICLES

July 1981

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FORWARD

The intent of this paper is to briefly address some of the effective methods utilized by foreign countries to enhance the mobility of wheeled and tracked vehicles.

Many of the systems which are discussed in this paper have been tested under the management of the US Army Tank-Automotive Command. The merits of each of these systems in regards to mobility performance has been evaluated.

Central Tire Inflation System (CTIS)

One of the most successful methods currently utilized to increase the mobility of wheeled tactical vehicles is the Central Tire Inflation System. Today, almost all Soviet and East European heightened mobility type trucks are equipped with CTIS.

Basically, CTIS is a system installed on a tactical truck with the intent to vary the vehicle tire pressures while on the move from within the vehicle cab. Figure 1 is a layout of the CTIS utilized on the Soviet ZIL-157, 2 1/2 ton cargo truck.

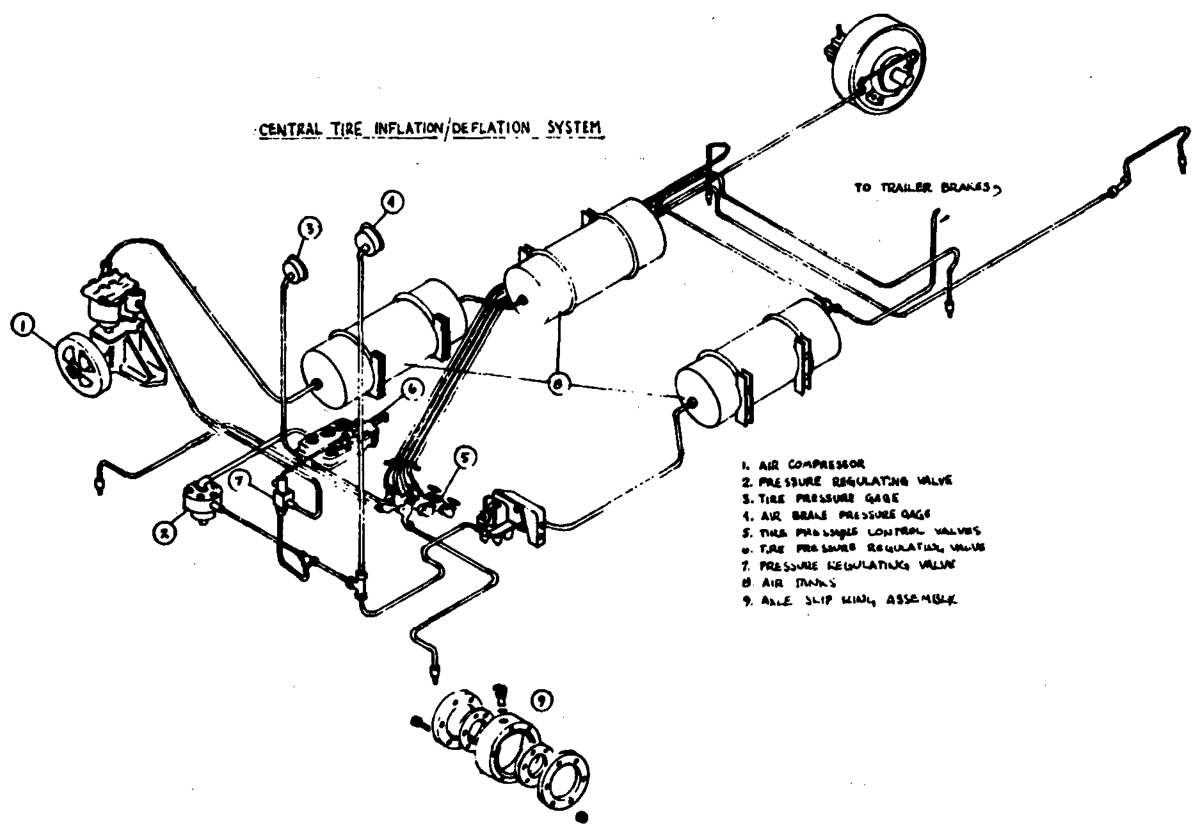

Figure 1. ZIL-157 CTIS

The CTIS on the ZIL-157 vehicle permits the vehicle operator to adjust the tire pressure through a range of 50 to 7 psi, hence, varying the tire footprint area whereas it increases by approximately 180% when deflated through the 50 to 7 psi range.

Table I shows a ZIL-157 tire (12:00 x 18) with given load at various inflation pressures and the corresponding tire footprint areas.

Table I - Tire Pressures vs Footprint Area

Load (lbs)	Tire Inflation (psi)	Gross Footprint Area (in^2)
2,330	8	142.67
2,330	20	94.93
2,330	42.7	62.70

Table II displays drawbar pull test data of the ZIL-157 vehicle operating in various soil conditions and tire pressures.

Table II - Maximum Increase of Drawbar Pull at Reduced Inflation Pressures

Soil Type	Inflation Pressure (psi)	Drawbar Pull (lbs)	Drawbar Increase (%)
Wet Loam	35	3,600	-
	15	4,300	19
	7	5,000	39
Fine Sand	35	5,000	-
	15	6,300	26
Course Sand	35	3,000	-
	15	5,000	66
Dry Loam	35	8,500	-
	15	9,200	8

Since CTIS does allow for increasing the vehicle tire footprint area, the vehicle has less ground pressure at the lower tire operating pressures. Lower ground pressures will in turn enhance the cross-country and soft soil mobility of a vehicle.

In Hub Planetary Final Drive

In hub, planetary final drive gear reduction is utilized by numerous foreign wheeled vehicle manufacturers. By incorporating this feature, the vehicle differentials can be designed more compactly and the axles and axle housings can also be made smaller, therefore permitting greater vehicle ground clearance. Hence, the higher the vehicle ground clearance, the greater the terrain traversing capability a vehicle will have.

This method of planetary gear reduction is utilized by the Soviets on the MAZ-537 Heavy Equipment Transporter, by the Czechoslovakians on the TATRA-813 Cargo Truck, and by numerous Western European truck producers. Figure 2 is a photograph of the tire/wheel assembly on the MAZ-537 vehicle showing the hub which houses the planetary gear drive.

Drop Axle Design

Another feature which is found on the Soviet UAZ-469 1/2 tonne light utility vehicle (Figure 3), the Italian VCL 1/2 tonne amphibious jeep (Figure 4), and several other Western European vehicles is the drop axle design. As with in-hub, planetary gear reduction, drop axles enhance a vehicles ground clearance. In addition to the compactness of the axle

differential and smaller diameter axles and housings, the drop axle design can permit the centerline of the axle housing to actually be higher than the centerline of the wheel hubs. Hence, by increasing the ground clearance of such a vehicle, the terrain traversing capability and mobility is also enhanced. Figure 5 is a photograph of the drop axle design utilized on the Italian VCL amphibious jeep.

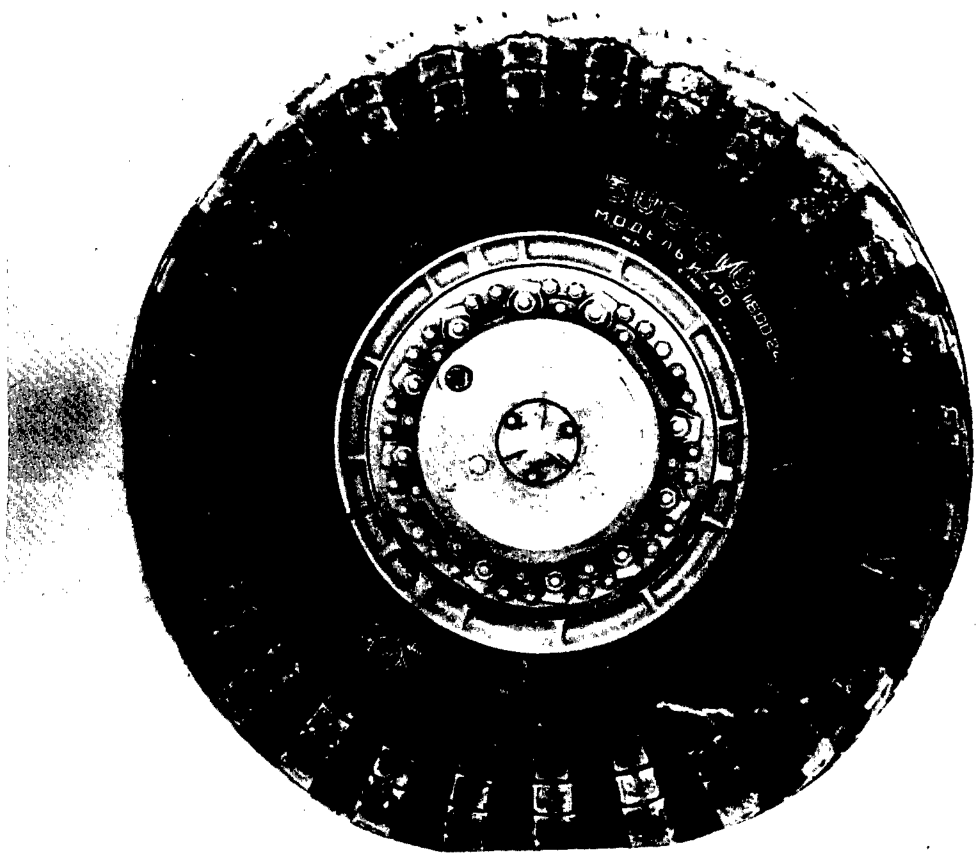

Figure 2. MAZ 537 Tire/Wheel Assembly

Figure 3. Soviet UAZ-469 Vehicle

Figure 4. Italian VCL Amphibious Jeep

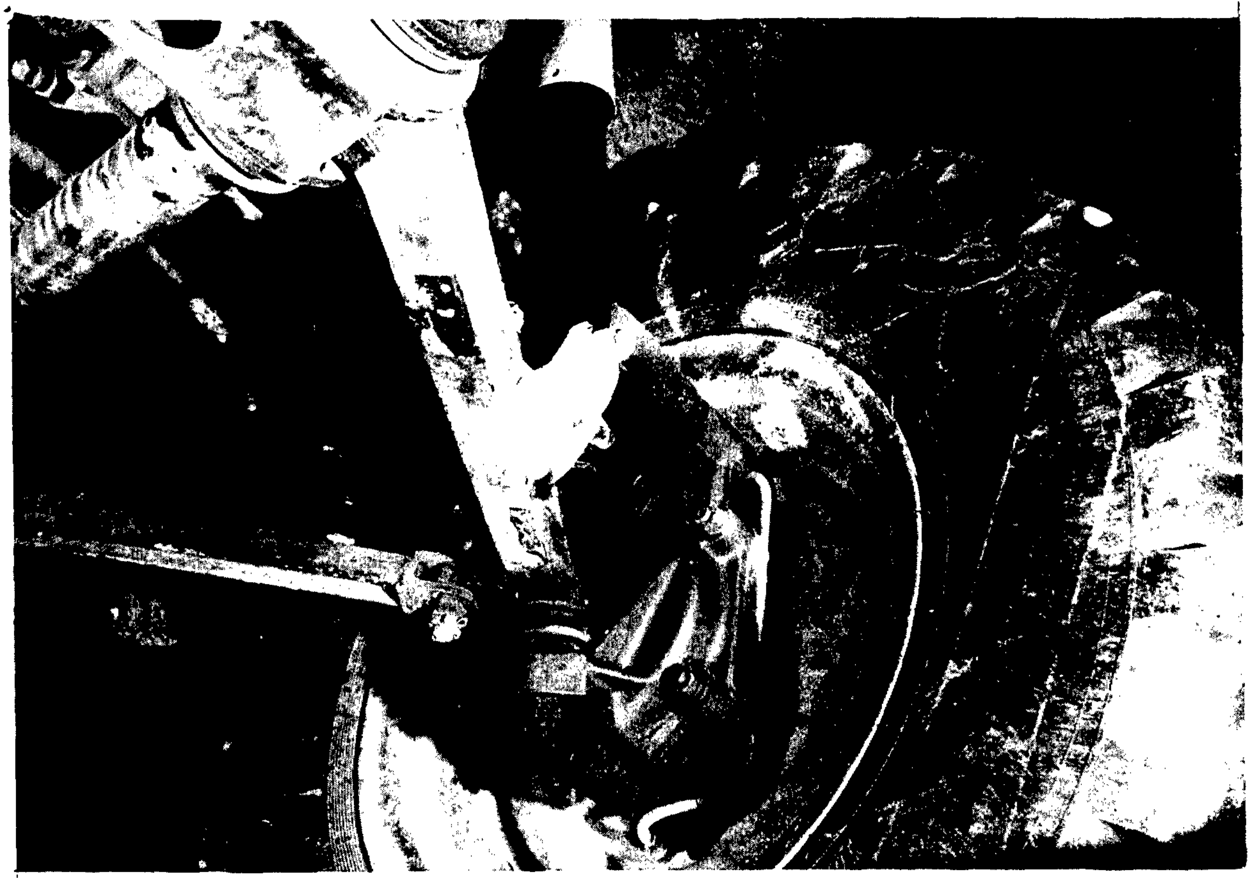

Figure 5. Italian VCL Drop Axle

Hydraulically Powered Trailer

One of the most interesting vehicle types tested was the Finnish A-45, 4x4 vehicle with a hydraulically powered trailer (Figure 6). The tractor is rated at 2 1/2 tonne and the trailer

Figure 6. Finnish A-45 Tractor/Trailer

The trailer unit has a single axle and is powered by two 60 hp hydraulic in-hub motors. Figure 7 shows a photograph of the hydraulic motor mounted on the A-45 powered trailer. Hydraulic pressure for the motors is provided by a pump which is driven off of the tractor engine. The hydrostatic propulsion system of the trailer is completely independent of the tractors mechanical drive train. When the hydraulic motors are engaged, the system acts as a 6x6 at speeds up to 10 km/hr. When speeds

greater than 10 km/hr are encountered, enterlocking controls disengage the hydraulic drive.

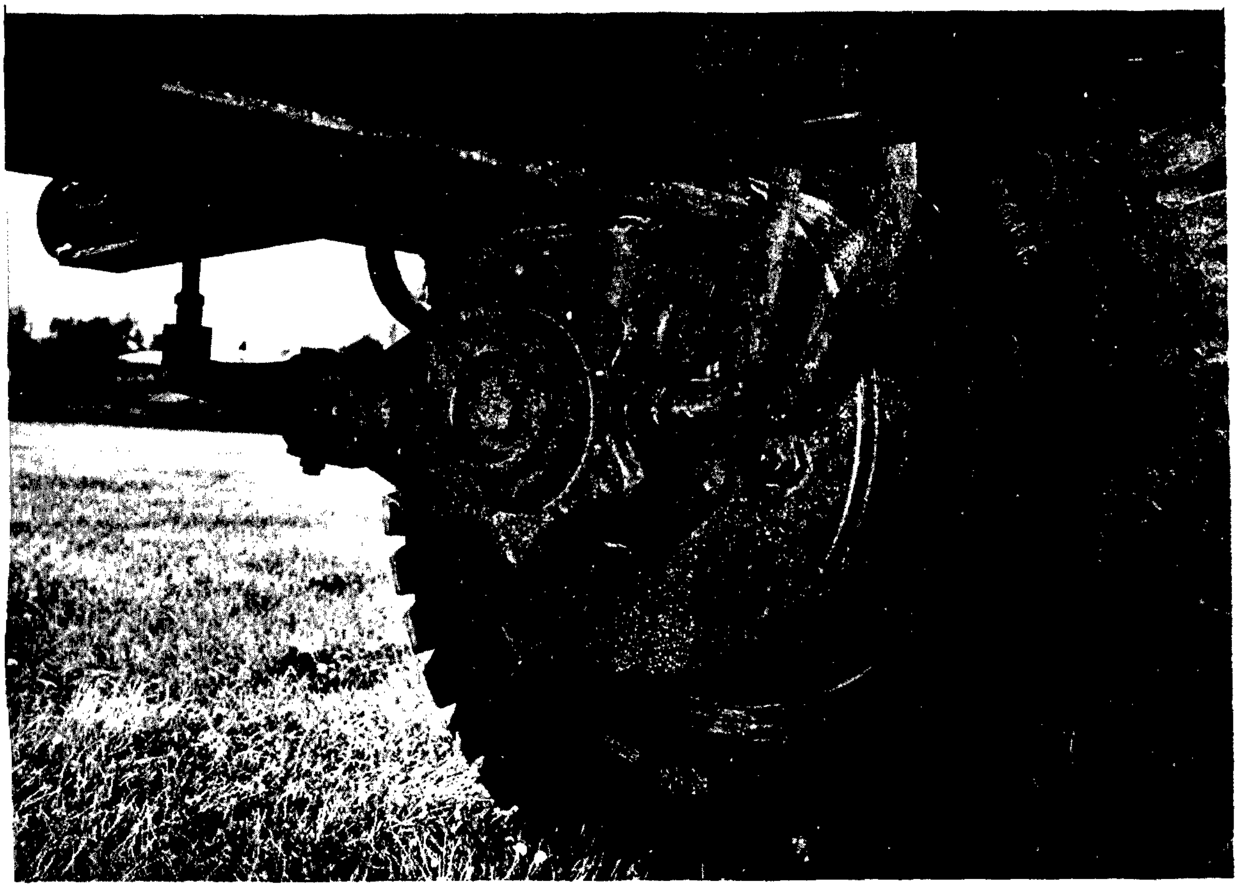

Figure 7. A-45 Hydraulic Motor

The A-45 tractor with the hydraulically powered trailer has the advantages of a light truck, but when required, can be used as a tractor unit for heavy trailers. Otherwise, no additional tractor weight (dead weight) is required to provide adequate tractive power in the powered trailer mode. Additionally, in adverse mobility terrain, the powered trailer has the capability to push the tractor.

On extensive tests which were performed on this system, it was determined that due to the hydraulic powered trailer, the flexible frame of the A-45 configuration and the locking differentials, the vehicle performed exceptionally well in difficult hilly terrain, but less than adequate in soft soil conditions.

Engesa Walking Beam Suspension

A mobility feature which was adapted and tested on the US 2 1/2 ton cargo truck (M35) and the 5 ton cargo truck (M813) with the intent to improve mobility was the Engesa total traction "Boomerang" suspension system. Figures 8 and 9 show this system installed on the Brazilian Engesa EE-25, 2 1/2 tonne, 6x6 cargo truck.

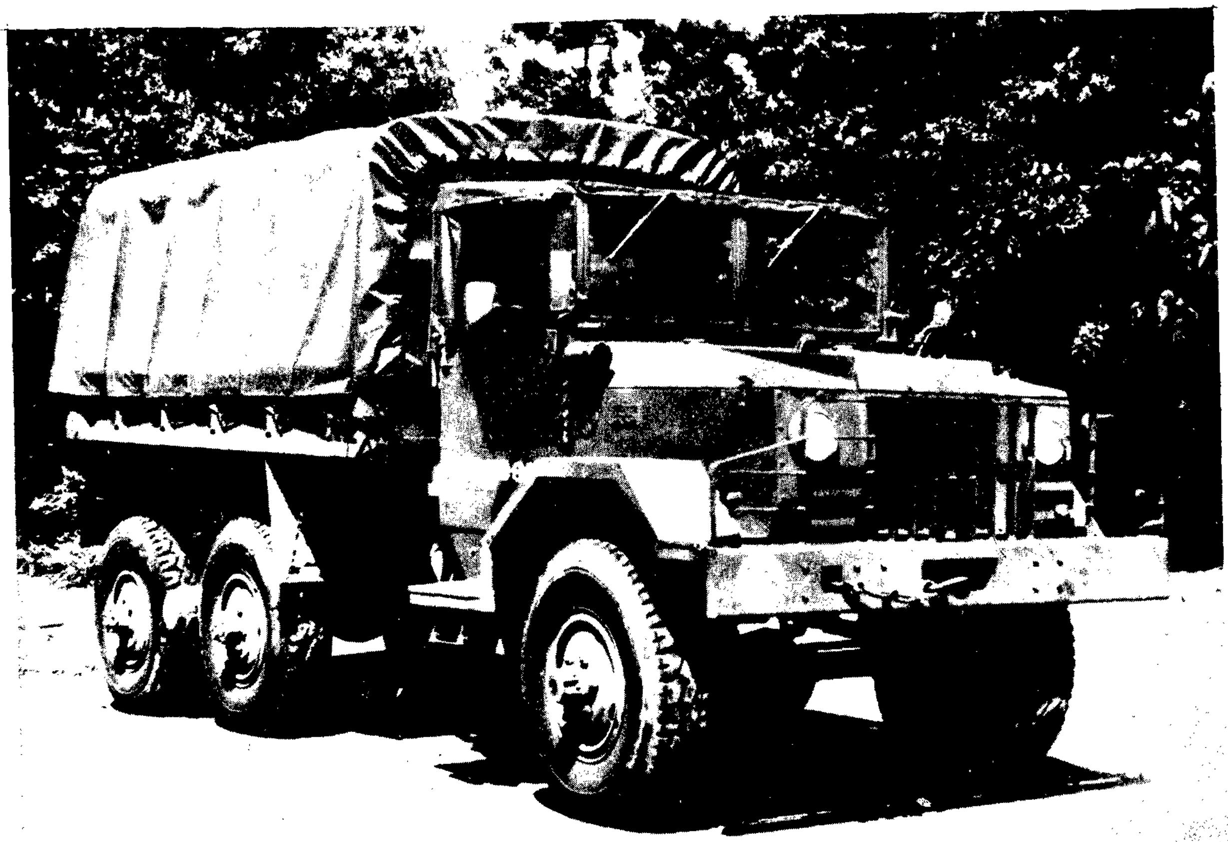

Figure 8. Engesa EE-25 Cargo Truck

Figure 9. Engesa EE-25 Cargo Truck

The uniqueness of this suspension system is that the rear bogie is a powered walking beam type suspension. The powered walking beams are gear driven and have locking differentials. Figure 10 is a top view of the Engesa powered bogie.

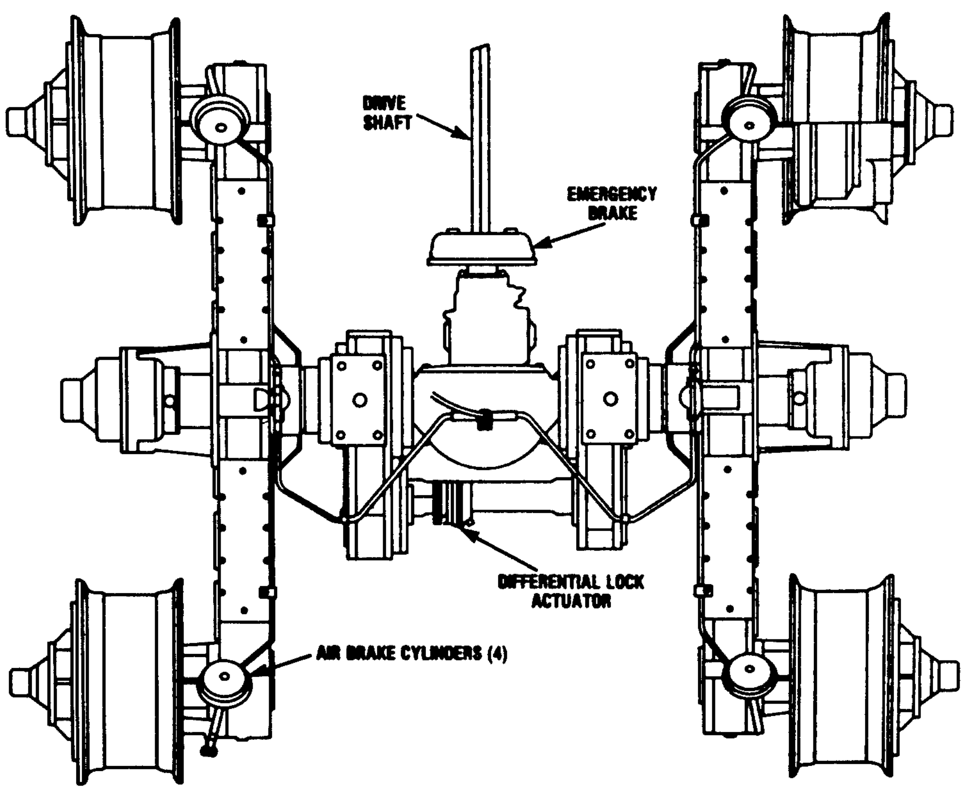

Figure 10. Engesa Powered Walking Beam

One of the primary advantages of this type of suspension system is that it has approximately 48" of wheel travel. The main factor which limits wheel travel on this type of system is the clearance allowed by the vehicle box or bed configuration.

The Brazilian EE-25, 2 1/2 tonne, 6x6 cargo truck claims a vehicle cone index (VCI) of approximately 26, which is considered good for cross-country mobility. Overall comparative testing of the M35 and M813 vehicles with and without the "boomerang" system indicated that the Engesa system performed better in vertical step climbing capabilities and in several isolated soft soil mobility courses than those vehicles with the conventional suspension systems.

Manual Locking Differentials

If the wheel slip of a vehicle can be controlled in critical situations, the mobility of a vehicle can be enhanced considerably. Various tactical trucks have been developed with conventional limited slip type differentials only to experience that unless the differentials are positively locked, wheel slip occurs at the expense of mobility.

Numerous foreign vehicle manufacturers have incorporated manual locking differentials in high mobility vehicles so as to minimize traction loss due to adverse mobility situations. The Czechoslovakian TATRA-813, 8x8, 8 tonne High Mobility Tactical Truck (Figure 11) incorporates axle and inter-axle differentials

that can be positively locked. The primary purpose of the inter-axle differential being to equalize the torque between the axle differentials of which it is mounted. In addition, the inter-axle differentials help eliminate tire scrub and drive train "windup" which occurs when the wheels of two different axles are forced to turn at the same speed.

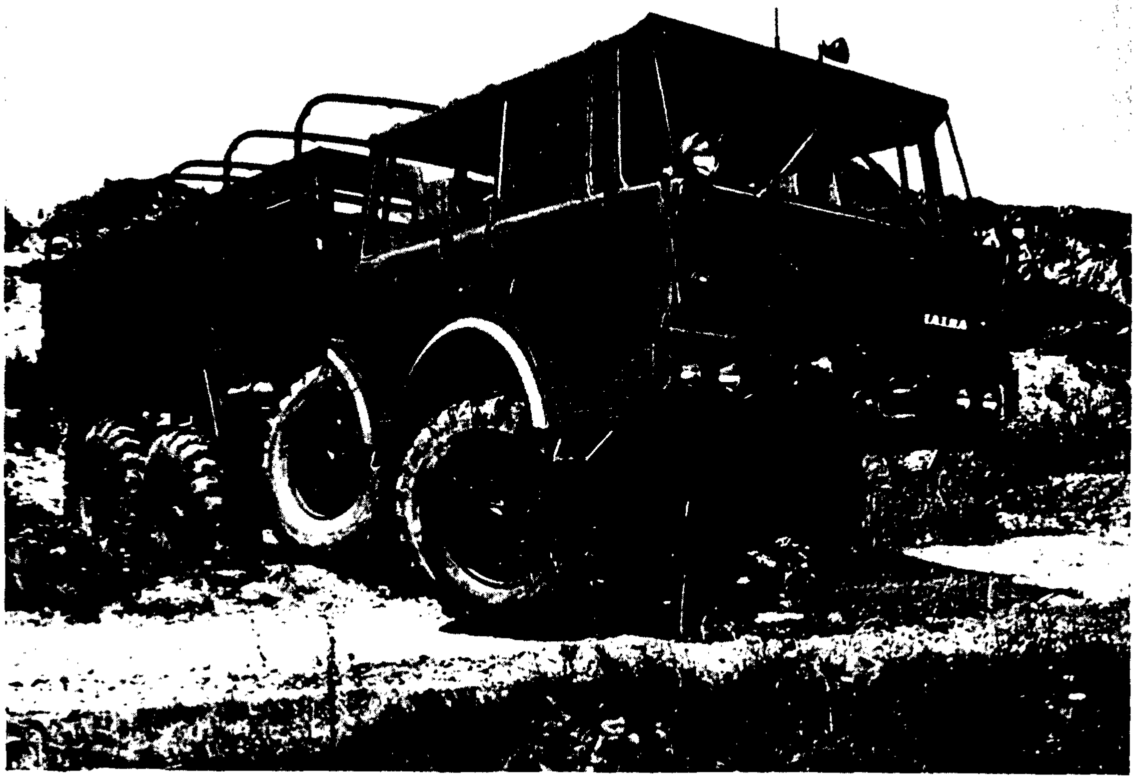

Figure 11. Czechoslovakian TATRA-813 Vehicle

The TATRA axle and inter-axle differentials can be locked/ unlocked electropneumatically by the vehicle driver. These controls are conveniently located on the vehicle dash panel (Figure 12). As an aid to the vehicle driver, the seven circular indicator lights mounted across the top of the TATRA dash panel "light-up" when the four axle and/or three inter-axle differentials become engaged.

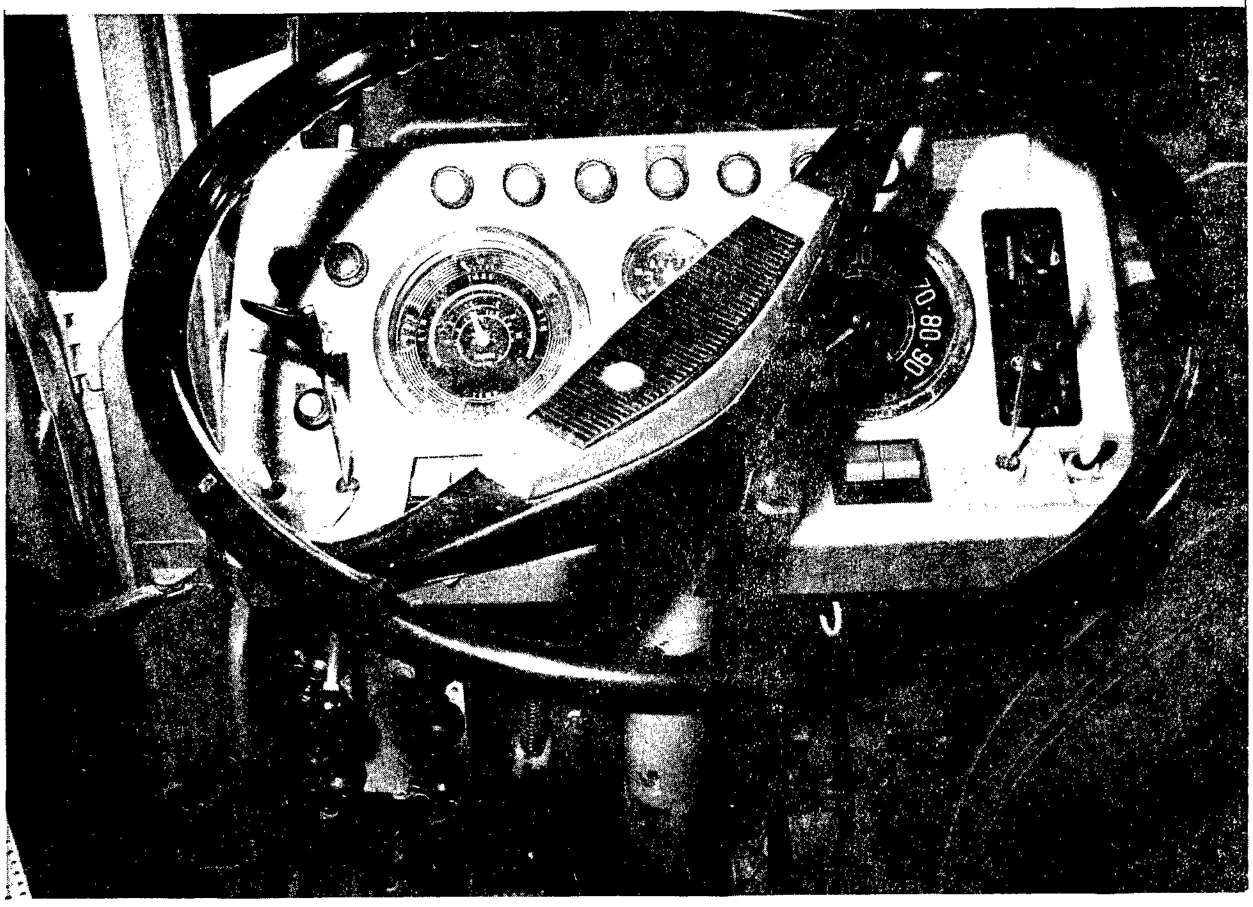

Figure 12. TATRA Dash Panel

The Finnish A-45, 2 1/2 tonne cargo truck incorporates manual locking differentials. From all tests conducted on the A-45 vehicle, one of the primary features that contributed to the mobility of this tractor was the manual locking differentials.

The Yugoslovian FAP 2026, 6x6, 6 tonne tactical cargo truck (Figure 13) has manual locking axle and inter-axle differentials. As in the TATRA vehicle, these locks are electropneumatically ac-

igure 14 illustrates the controls in the FAP 2026 ve-

activates the axle and inter-axle differential locks.

Figure 13. Yugoslovian FAP 2026 Vehicle

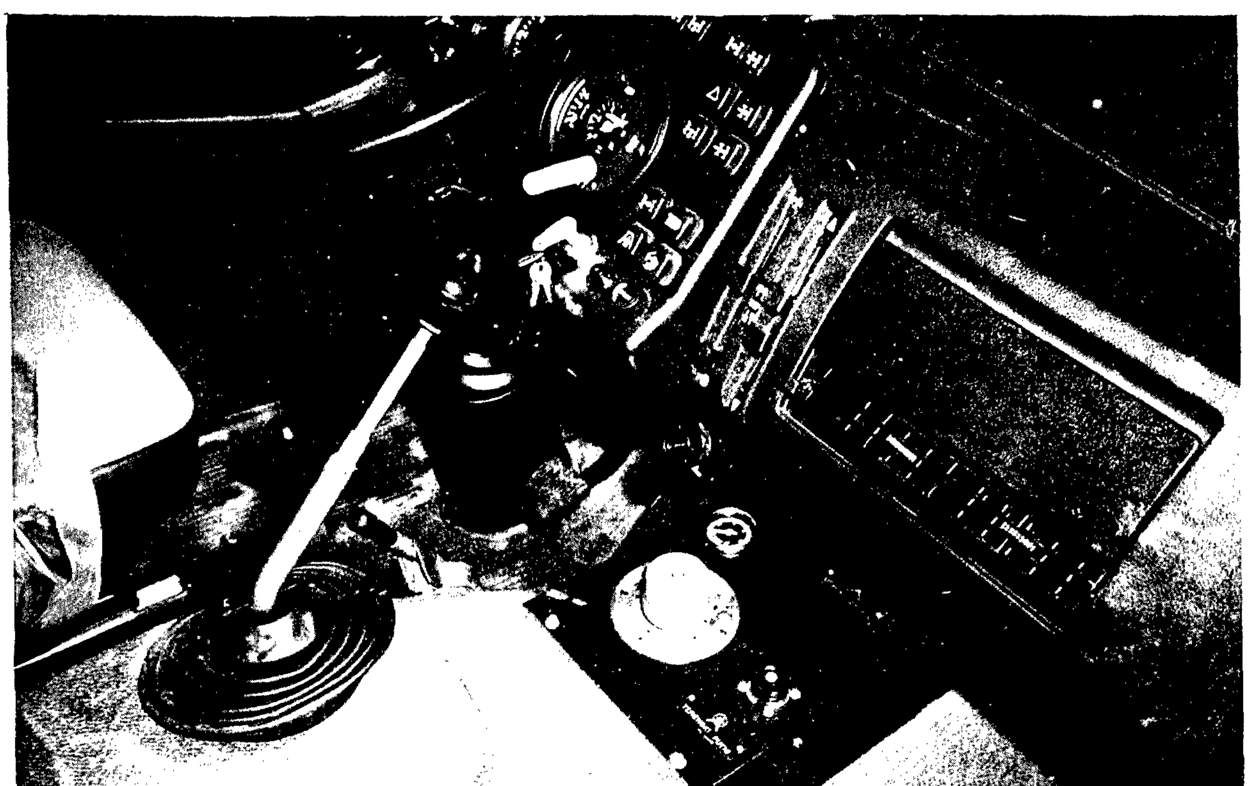

Figure 14. FAP 2026 Dash Panel

As with any system incorporated into a tactical vehicle, ultimate results are achieved only if the system is properly utilized. When using the manual locking differentials, the vehicle operator must be selective. Unlike the conventional limited slip type differentials which are somewhat automatic, the driver of a vehicle with manual locking differentials must know when, and when not to activate this system. It can be a very valuable tool when properly used as an off-road mobility aid.

Independent Swing Axles

One of the primary factors that determines the degree of mobility a wheeled vehicle will have in adverse terrain is the amount of tire contact area which is exposed to the terrain. Assuming that all else is equal, an 8x8 vehicle that is capable of having all eight tires in contact with the ground in a given terrain will be more mobile than an 8x8 vehicle that has only seven tires in contact with the ground. Hence, in comparing a vehicle with solid axle design to a vehicle with swing axle design, the swing axle type is not as rigid and is more apt to follow the terrain profile.

The TATRA-813 tactical cargo truck is designed with independent swing axles, whereas there are no "U" joints between the differentials and the wheels (Figure 15).

The independent swing axles slide around the central tube axle differential (Figure 16) by means of two locating forks

whereas all suspension reactions are taken up by these forks. The crown gears attached to the axle, meshes with the pinion gear within the differential.

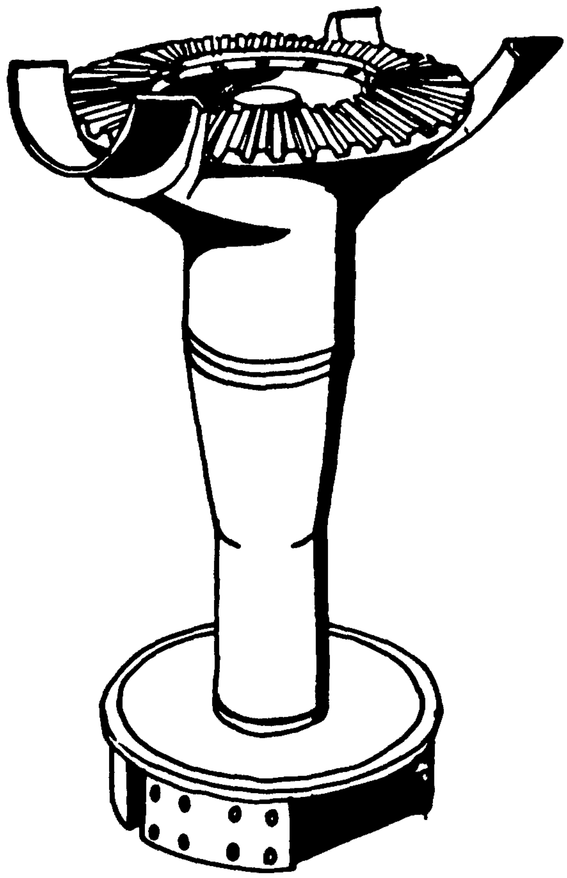

Figure 15. TATRA Swing Axle

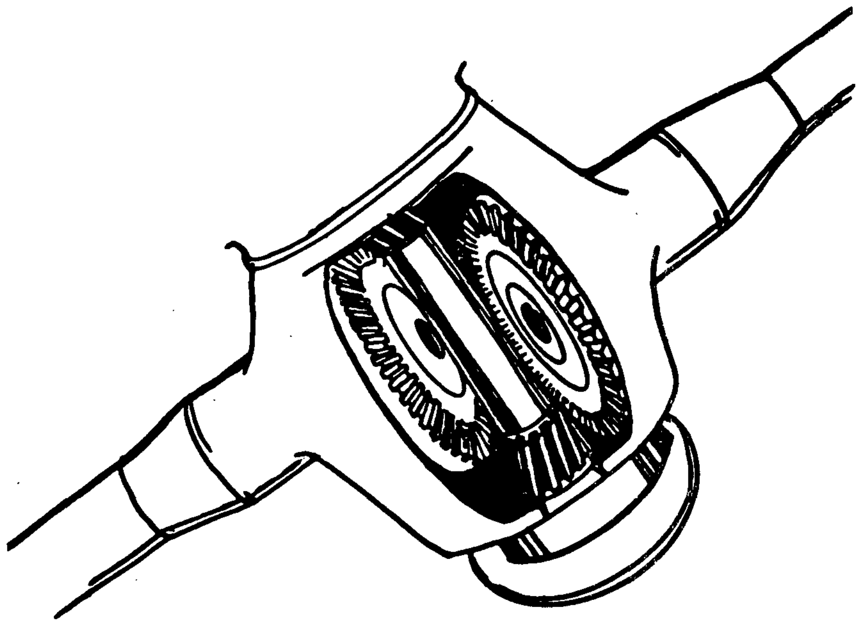

Figure 16. TATRA Axle Differential

In a solid axle design, when the vehicle negotiates an obstacle, the axle (due to its rigid configuration) can make the vehicle somewhat unstable. If a vehicle with swing axle design (such as the TATRA-813) were to negotiate this same obstacle, the vehicles angular displacement would be less.

Despite the fact that the TATRA vehicle is somewhat underpowered (16.5 Hp/Ton), testing has indicated that it is an extremely mobile vehicle over a variety of adverse terrains. One of the primary factors accountable for this outstanding mobility is due to the swing axle configuration.

From a ride dynamics standpoint, the TATRA vehicle is very impressive. A vehicle that displays such exceptional ride dynamics will have a high "speed made good" over a variety of adverse terrains.

Auxillary Powered Wheels

The Soviet BRDM-2, 4x4, Armored Amphibious Scout Vehicle (Figure 17) has powered auxillary wheels which are built into the vehicle.

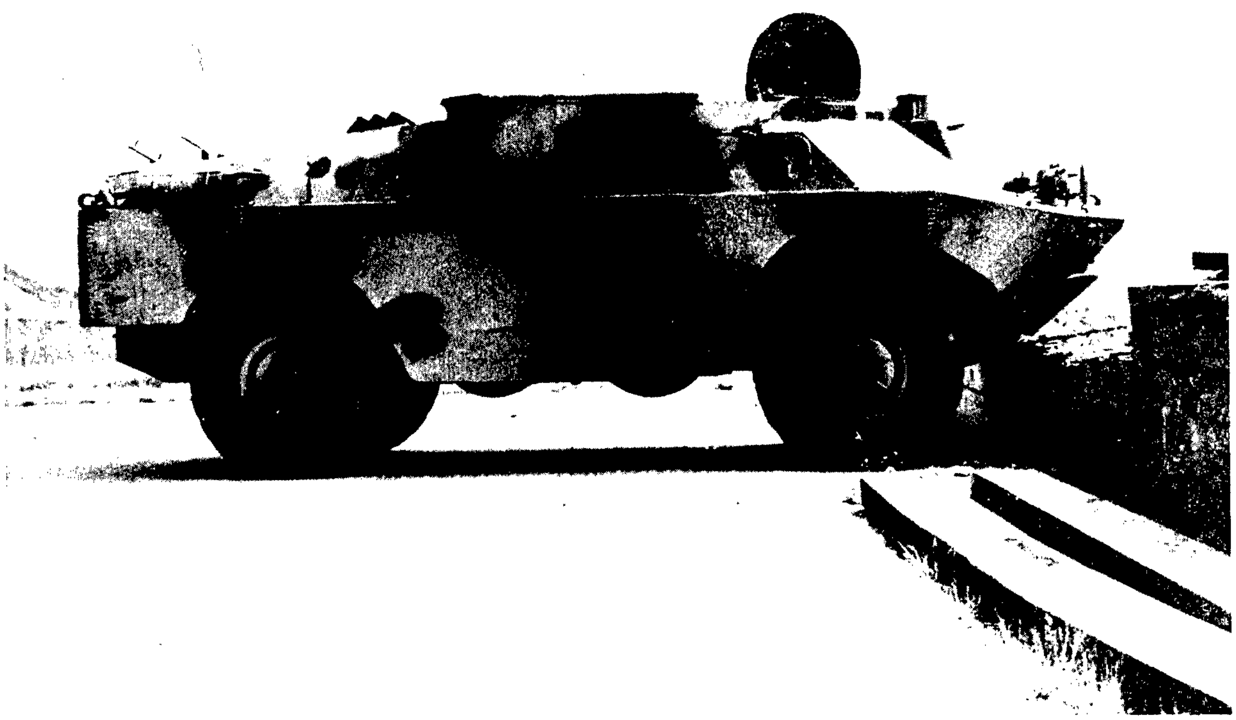

Figure 17. BRDM-2 Vehicle

The purpose of this configuration is to aid the vehicle in trench crossing operations.

In the event that the vehicle encounters an area that requires the use of these wheels, they are simply lowered by the vehicle operator (Figure 18). The wheels are chain driven from a power take-off from the vehicle transfer case. When the wheels are no longer needed, they are elevated back up into the raised position. All raising and lowering of these wheels is hydraulically actuated.

Figure 18. BRDM-2 Vehicle (Lowered Auxillary Wheels)

Trench crossing for a wheeled vehicle is normally limited by the vehicle tire size, wheel base and center of gravity. However, by utilizing these auxillary powered wheels, the problem of negotiating trenches is reduced considerably.

Automatic Two-Speed Transfer Case

The Swedish SAAB-SCANIA (SBAT-III), 6 ton, 6x6, tactical cargo truck (Figure 19) has a two-speed transfer case which can be shifted on the "move".

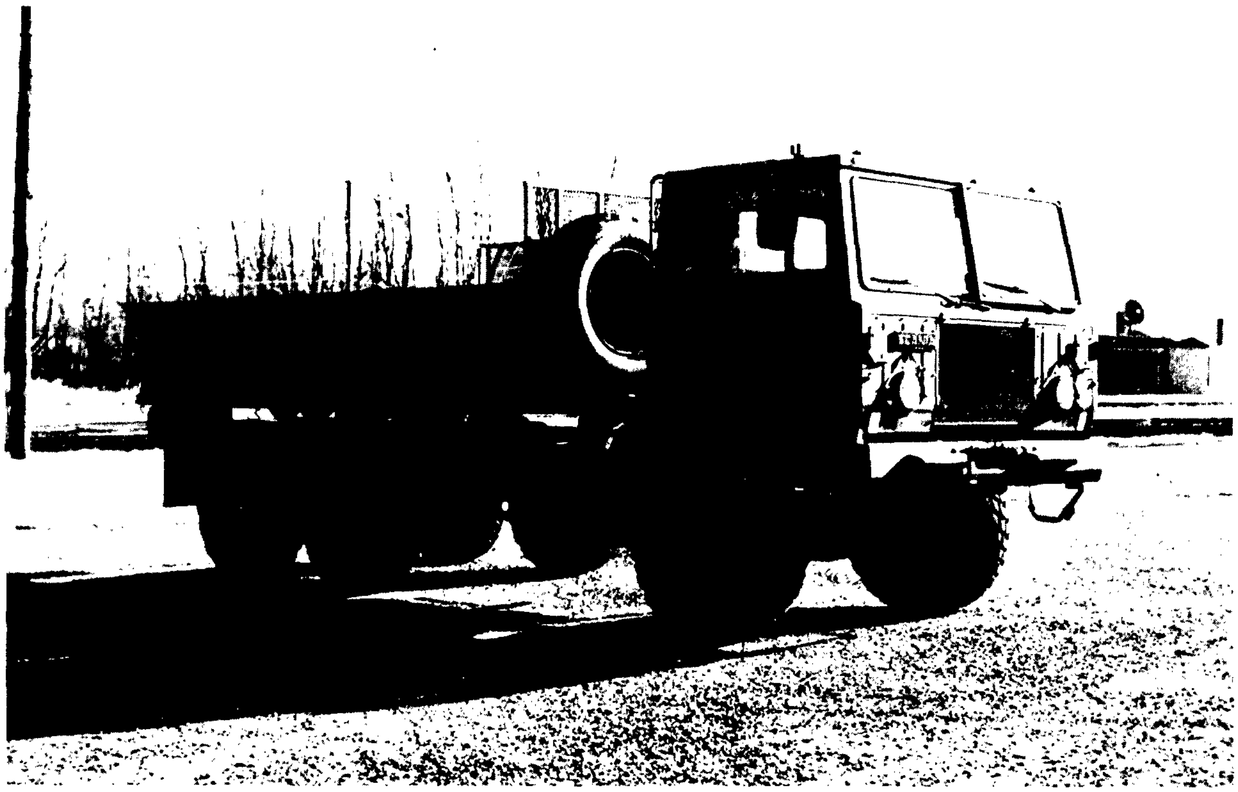

Figure 19. Swedish SAAB SCANIA SBAT-III

Unlike the conventional transfer case that can only be shifted after the vehicle comes to a stop, the SAAB-SCANIA transfer case is shifted simply by turning a switch which is mounted on the console to the right of the driver. The

advantage of such a feature can significantly effect the mobility of a vehicle from the standpoint of "speed made good." Such a feature allows the vehicle operator to change his mode of driving from highway to cross-country operation without bringing the vehicle to a stop by shifting from high to low range. In addition, it gives the vehicle driver confidence due to the ease of operation.

Downshifts may be preselected with this control at any speed, however, the shift does not actually take place until the vehicle speed drops below 18 Km/Hr and the accelerator pedal is released.

MOWAG Run-Flat Tires

As a method to obtain a tire with run-flat capability and to enhance the mobility of a rubber-tired wheeled vehicle, the Swiss MOWAG wheel was developed. The MOWAG wheel (Figure 20) is a combination assembly which consists of a high pressure (80 psig) pneumatic tire, plus solid aluminum wheel sections or grousers which are similar to paddle type wheels which are bolted to the inner and outer side of the pneumatic tire. The MOWAGs wheels which were tested, were mounted on a Commando M706, 4x4 armored car (Figure 21). The rear wheels of the test vehicle were equipped with additional add-on grousers on the outside of wheel (Figure 22).

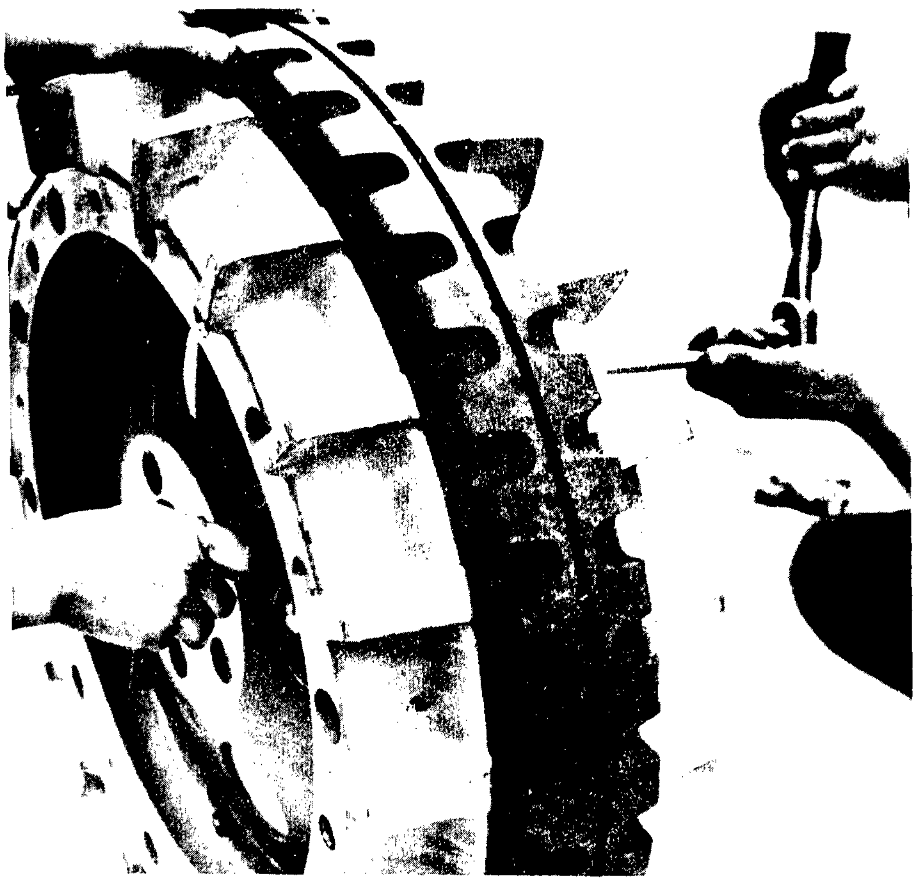

Figure 20. MOWAG Tire/Wheel Assembly

Figure 21. M706 Vehicle With MOWAG Wheels

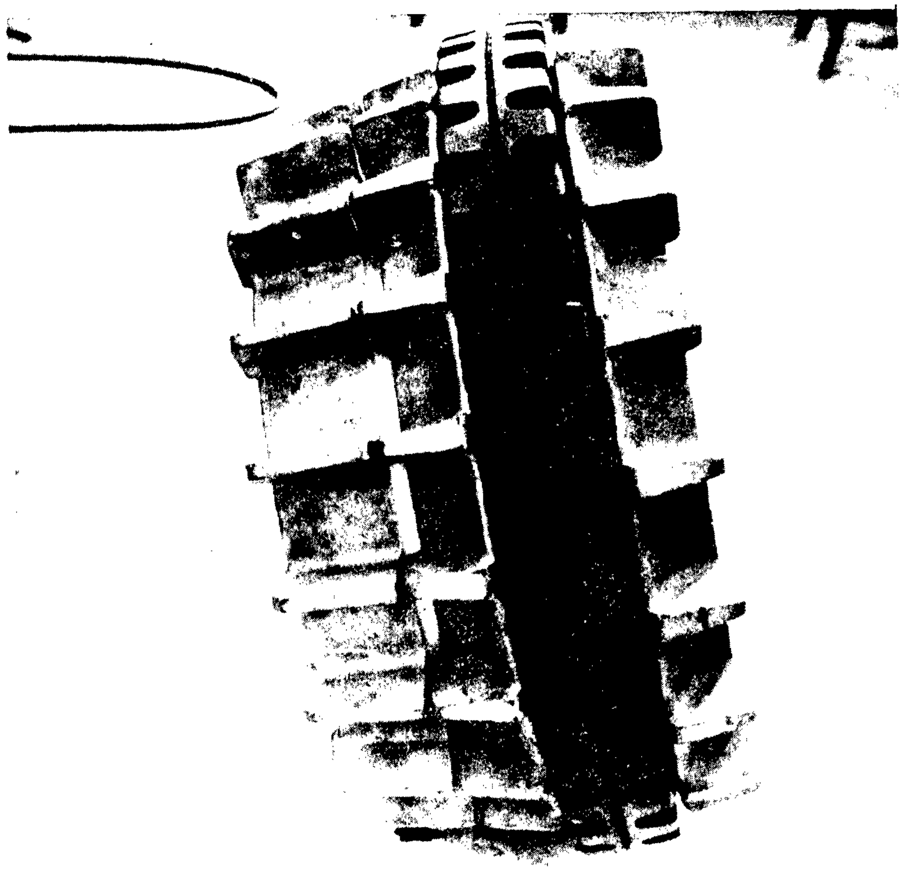

Figure 22. Add-On Grouser On Rear Wheels

The MOWAG's wheels provided good mobility in soft soil conditions, particularly in mud. When the MOWAG tire/wheel assembly was tested in rocky cross-country courses, it experienced problems with the grousers breaking off, hence, limiting the operation in this type of terrain.

Positive Pitch Control

An interesting feature which can be fitted to the BV206 tracked articulated vehicle is positive pitch control (Figure 23).

Figure 23. BV206 Tracked Articulated Vehicle

This system employs a hydraulic cylinder which is mounted between the front and rear vehicle units just above the articulated joint and the two yaw cylinders (Figure 24).

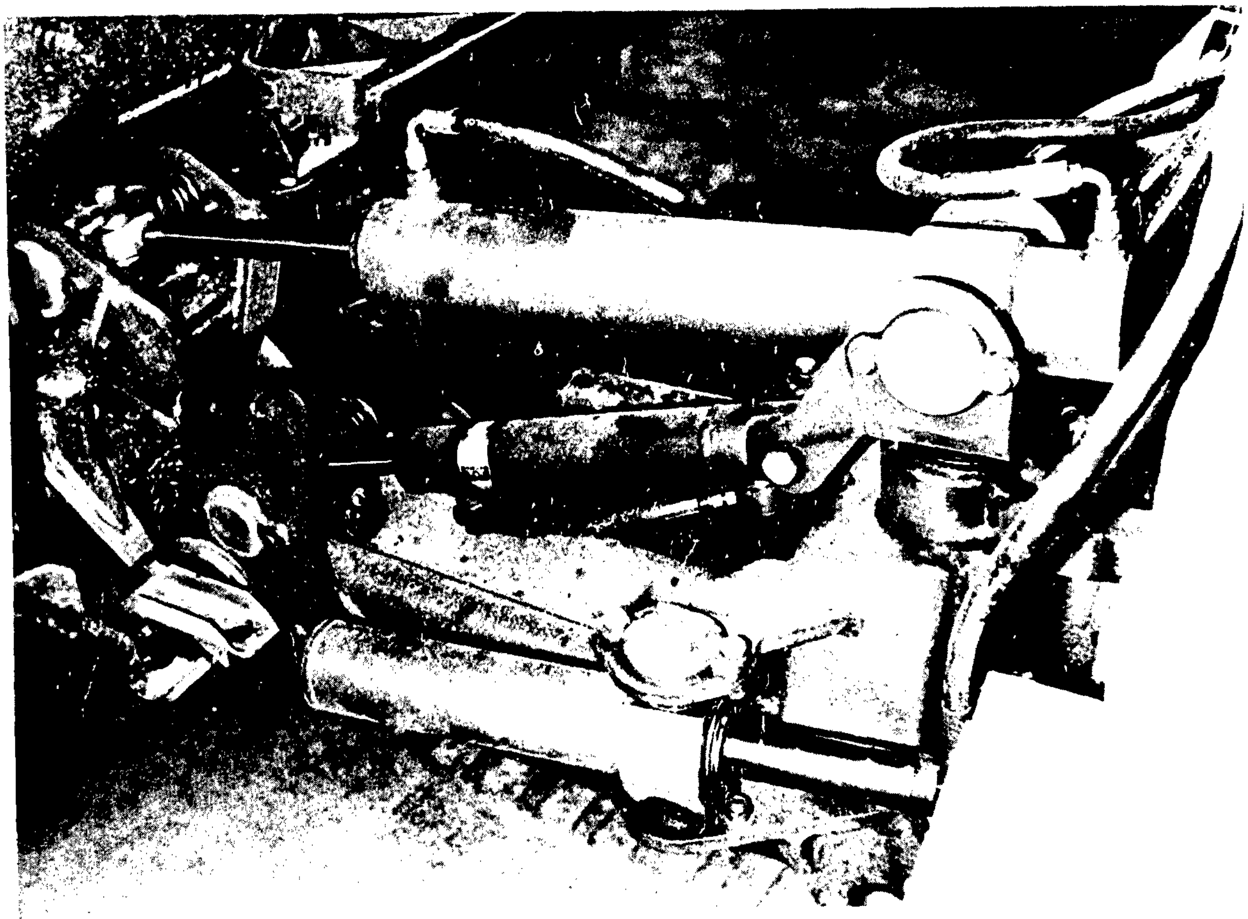

Figure 24. Positive Pitch Control/Yaw Hydraulic Cylinders

The positive pitch control system is utilized on the anti-tank version of the BV206 vehicle with the intent to help position the front armament carrying unit in a better firing attitude. From a mobility viewpoint, it has not only the obvious capability of raising the forward vehicle unit to increase its capability to climb a step or obstacle, but can also give the operator a means of shifting the weight and attitude of the vehicle to further enhance slope climbing performance. To activate the positive pitch control system, the driver simply

activates a control lever which is located to the left of the driver seat.

The US Army has conducted several test programs on articulated vehicles which incorporate systems that assist in varying the pitch between the vehicle units. It is hopeful that the test and evaluation of the BV206 vehicle with positive pitch control will enhance this technology base for articulated vehicle mobility.

Studded Track Shoe

Several foreign track manufacturers have designed track shoes with the capability to accommodate a device to be utilized for traction on ice. The German Diehl 213B track shoe (Figure 25) has a tapered through hole molded into the shoe.

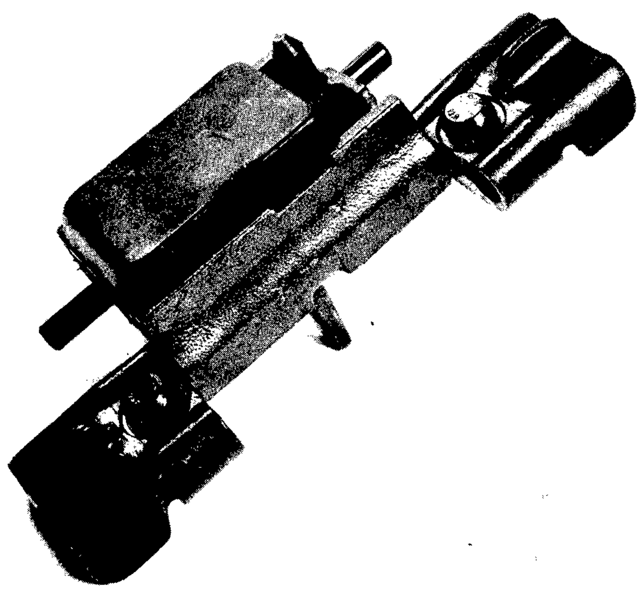

Figure 25. Diehl 213B Track Shoe

If and when the vehicle is driven on an icy surface, tapered steel pins (Figure 26) are driven into the corresponding holes in the vehicle track. When the pins are no longer required for mobility on ice, they are simply tapped out from the inner side of the track. This has been proven to be a relatively cost effective method utilized to obtain mobility for a tracked vehicle on ice.

Figure 26. Diehl Track and Tapered Pin

Water Jet Propulsion

Mobility is normally discussed in terms of how well a vehicle can negotiate a type of terrain. However, it becomes obvious by observing vehicle designs that few tracked or wheeled vehicles are prepared for amphibious operations. Only a small percentage of vehicles are capable of swimming and if so, they are not capable of maneuvering well in the amphibious mode.

By observation, the Soviets are concerned about designing a vehicle that has amphibious capabilities. Below (Figure 27), is a photo of the Soviet BTR-60P amphibious armored personnel carrier.

Figure 27. BTR-60P Vehicle

This vehicle is equipped with an inherently designed water jet propulsion system which is driven by power take-offs from both vehicle engines. The intake grill for the water jet is on the underside of the vehicle hull. Maneuvering in the amphibious mode is accomplished by controlling the opening and closing of the water jet gates as well as by turning the first and second axles.

Figure 28 is a rear view of the Soviet BRDM-2 amphibious armored scout vehicle. The water-jet for this vehicle is a similar configuration to the BTR-60P vehicle.

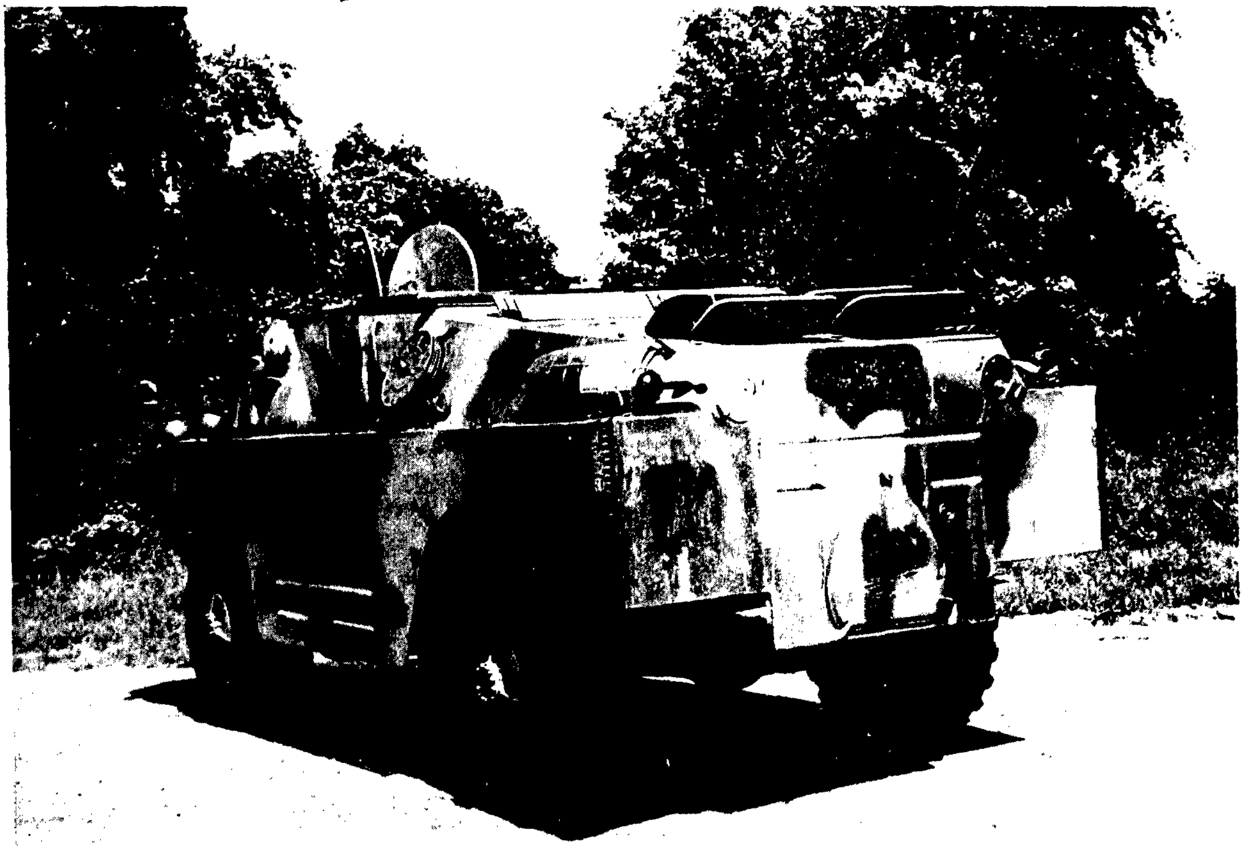

Figure 28. BRDM-2 Vehicle

The Soviet BTR-50P amphibious armored personnel carrier (Figure 29) is propelled by two water jets, one on each side, at the rear of the vehicle. A rotating gate, which is controlled by the vehicle driver, is mounted at each water jet exit port to control the flow of water which, in effect, steers the vehicle in the water. On each side of the vehicle hull, just above the sixth road wheel, is a reverse thrust port which is used for steering as well as reversing the vehicle in the water. When the gate is positioned over the water jet opening, the flow of

water is forced out of this port on an angle of approximately 20 degrees to the longitudinal axis of the vehicle.

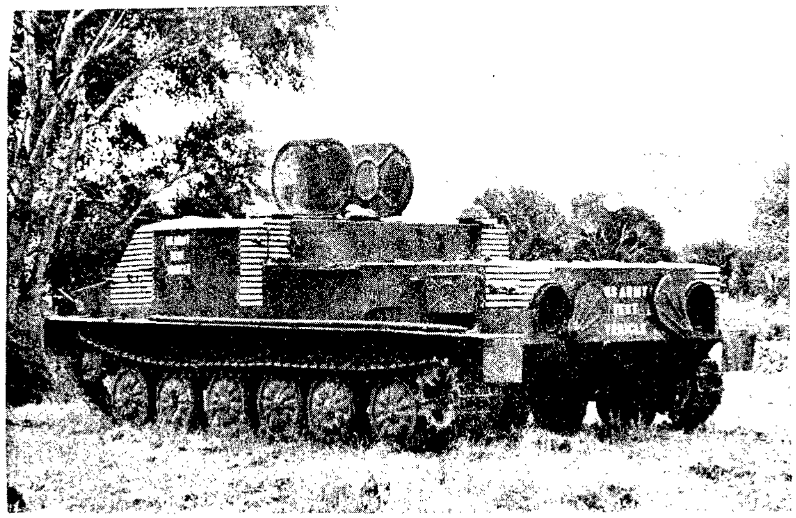

Figure 29. BTR-50P Vehicle

An obvious advantage of a water jet system that is inherently designed into the vehicle is that it is able to operate in the amphibious mode when necessary. No kit or laborous preparation is necessary prior to assuming the swimming mode. Hence, the overall vehicle mobility can be expected to improve by incorporating this type of system.

SUMMARY

In summary, there are many well proven systems which can be configured into both tracked and wheeled vehicles which will enhance overall mobility. If the mobility design requirements of a vehicle are properly represented in the vehicle development stage, it can enhance the probability of obtaining a cost effective vehicle that performs well. This paper has merely "scratched the surface" on the numerous systems that could be incorporated into vehicles to achieve these design objectives.